1980 Annual Report to
Energy Fuels Nuclear, Inc.
"Rehabilitation of Disturbed Sites and Spoil Piles of SE Utah Uranium Mines"

by

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ANNUAL REPORT OF ACTIVITIES

Working within the time frame of the contract, eight trips were made to one or more mine sites during the year. These were for land preparation, fencing, direct seeding or for collecting plant propagation material. The high elevation site was changed from the Glade Mine as previously planned to an old mine site on the north slope of the Big Notch on Elk Ridge which will be referred to in these reports as the Big Notch Mine.

Seed from numerous species collected from 1979 and 1980 trips were cleaned and stored for later use as well as being used in the 1980 fall direct seeded planting and for germinating and growing plants in containers. Seed of a few species have been planted in a nursery for obtaining bare-root planting stock. Wildings were also obtained at the Big Notch site and planted in containers.

I. SITE PREPARATIONS

General land grading at each of the four sites was accomplished by Energy Fuels Nuclear personnel using large equipment. The size of the spoil piles limited the size of the area for conducting these studies.

A. Xeric Sites

A basic plot design for the three xeric sites consisted of two 40-inch water harvesting slopes in a vee shape with a planting area in the bottom. As a comparison for the water harvesting slopes a flat fallow area would be used with a special treated planting area extending through both. This seed bed (soil

treatment area) was made by digging out a trench approximately 6 inches deep, 16 inches wide and 33 feet long. A fertilizer mix of ammonium nitrate (50 lbs. N/acre) and treble super phosphate (100 lbs. P_2O_5 per acre) plus a covering of wood chips at 2.5 tons per acre were broadcast in the bottom of the trench. The trench was then filled with locally available soil and then mixed by roto-tilling. There are four replications at each of these three sites. Other treatments were instituted at each site depending on space as shown on the plot preparation and field plans.

1. Sahara Mine Site (Plan 1)

In addition to the basic plot design as explained above two additional trenches were dug and prepared as in the basic design with water harvesting slopes and flat plantings, but no wood chips were used. Two other sections were prepared. One of these consisted of a spoils (tailings) area being fertilized versus no fertilizer with both areas being roto-tilled to cover the fertilizer and for uniformity. The other consisted of the same two treatments - fertilizer versus no fertilizer - and then being covered with 5 - 6 inches of sand (soil material available for use at this site). The land preparation and treatments were accomplished on April 3, 4 and 28, 1980 with the area being fenced with a rabbit proof netting September 9, 1980.

2. Wee Hope Mine Site (Plans 2 and 3)

Two separate areas were prepared at this site due to the small size. At one of these sites (A) is located the basic water harvesting design. Another plot at this site contains two treatments, fertilizer and no fertilizer, with both covered with approximately 2 inches of soil and then mixed by roto-tilling.

Location B was leveled with two furrows 6 - 8 inches deep and 46 feet long dug through the middle. These two locations were prepared April 29 and 30 with both locations fenced with rabbit proof netting on September 9, 1980.

3. Repete Mine Site (Plan 4)

Late precipitation and the nature of the soil delayed plot preparations until June 17-19, 1980. Section A at this location contained the basic water harvesting design. The two treatments, fertilizer plus no fertilizer, were applied to Sections B and C with Section B then being covered with 3 - 4 inches of soil. Both sides of Section C were roto-tilled to cover the fertilizer and for uniformity. Four trenches were dug in the north half of Section D with fertilizer broadcast in the bottom and then filled with soil. The other half of this section was left. A rabbit proof fence was installed September 8, 1980.

B. Mesic Site

No water harvesting slopes are needed at the Big Notch site as it is assumed moisture will be ample at this elevation for plant

establishment. The area was graded by Energy Fuels Nuclear personnel, June 19, 1980. In the process a number of shrub wildings, especially rubber rabbitbrush, were destroyed. A good portion of the flat area in front of the portal and the spoils slope is infested with field bindweed. The amount of soil material on the flat area is extremely shallow. A border ridge was constructed to prevent runoff water from the escarpment and portal cut from contaminating the area to be planted. Additional preparation work on the site was accomplished July 31, 1980. Shrub wildings, grass plugs and some seeds along with an inventory of the vegetation was obtained at this time. Due to the amount of vegetation available for wildlife and the difficulty presented in trying to erect a fence at this location, none was erected. No plot preparation plan is included as only a rough sketch was drawn with a few measurements.

II. FALL PLANTING
(Fall planting diagrams are included)

A. Sahara Mine Site (Plans 5 and 6)

1. Section A.

Seed from five shrub species were hill planted at approximately 40 inch spacings (1 m) in the six trenches of Section A. Transplants will be planted in between during the spring. The five species planted October 10, 1980 were:

Symbol	Common Name	Scientific Name
ATCA	Fourwing saltbush (S-537-79)	*Atriplex canescens*
ATCO	Shadscale (S-541-79)	*Atriplex confertifolia*
ATCU	Cuneate saltbush or moundscale	*Atriplex cuneata*
SAVE	Greasewood	*Sarcobatus vermiculatus*
GRBR	Spineless hopsage	*Grayia brandegei*

Rows 1 and 2 were covered October 29 with a layer of bitterbrush chips to serve as a mulch. It was observed at this date that many of the greasewood and spineless hopsage seeds planted on October 10 had germinated and emerged due to precipitation during this period. It is not known if these tender seedlings will survive overwinter.

2. Section B

In Section B, ten species were each direct seeded in 20 inch (50 cm) rows in the plot area consisting of four treatments of waste (spoils); waste plus fertilizer; fertilizer on waste covered by soil; and waste covered by soil. Species planted on October 10, 1980 were:

Symbol	Common name	Scientific name
HIJA	Galleta grass (Viva)(SCS)	*Hilaria jamesii*
ATCA	Fourwing saltbush (S-521-79)	*Atriplex canescens*
ATCO	Shadscale (S-541-79)	*Atriplex confertifolia*
SPAI	Alkali sacaton (S-539-79)	*Sporobolus airoides*
ACTOR	Mat Saltbush (S-478-79	*Atriplex corrugata*
ERIO	Perennial buckwheat(S-512-79)	*Eriogonum microthecum*
ORHY	Indian ricegrass(USU 214-215-75)	*Oryzopsis hymenoides*
ATWE	Welsh saltbush (S-532-79)	*Atriplex welshii*
CELA	Winterfat (S-505-79	*Ceratoides lanata*
SPHA	Globe mallow (S-477-79)	*Sphaeralcea parrifolia*

It was observed on October 29 that seedlings of winterfat planted October 10 were emerging in the soil (sand) covered plots.

The earth portion (half) of Section B, not shown on the planting diagram was left open for spring planting of transplants.

3. Section C

The same five shrub species that were direct seeded in

Section A were planted in rows 40 inches (1 m) long on October 29, 1980 following the earlier rains. One half of each row (20 inches) were covered with bitterbrush chips as a mulch and the other half left uncovered for comparison as shown on the plot plan.

The north side and the east portion were left open for spring transplants.

4. Section O

A small observation study was placed outside the fence exclosure to the west. This consisted of two short rows on the level and three on the slope. The same five species that were seeded in Section A and C were also seeded here in rows on October 29,1980. Part of each row was covered with bitterbrush chips with the other part left uncovered except for covering the seed with soil.

B. Repete Mine Site (Plans 7 and 8)

1. Section A.

In this water harvesting comparison five shrub species were planted in hills at approximately 40 inch spacings, October 8, 1980. Interplanted between the hills will be the spring planted transplants. The five species planted were:

Symbol	Common Name	Scientific Name
ATCA	Fourwing saltbush	*Atriplex canescens*
ATCO	Shadscale	*Atriplex confertifolia*
ATOB	Broadscale saltbush	*Atriplex obovata*
SAVE	Greasewood	*Sarcobatus vermiculatus*
GRBR	Spineless hopsage	*Grayia brandegei*

2. Section B

Nineteen species were seeded in eight rows with rows being 50 cm apart and each species planted 50 cm in each row. The east half of each plot was planted October 9, 1980 with the west part being left for spring transplants.

The following species were planted:

Symbol	Common Name	Scientific Name
GRBR	Spineless hopsage	*Grayia brandegei*
ATOB	Broadscale saltbush	*Atriplex obovata*
ORHY	Indian ricegrass (USU 214-215-75)	*Oryzopsis hymenoides*
AGCR	Fairway crested wheatgrass	*Agropyron cristalum*
ATCON	Shadscale	*Atriplex confertifolia*
ATCA	Fourwing saltbush	*Atriplex canescens*
SAVE	Greasewood (S-525-79)	*Sarcobatus vermiculatus*
SPAI	Alkali sacaton	*Sporobolus airoides*
ATCU	Cuneate saltbush or moundscale (S-499-79)	*Atriplex cuneata*
MEOF	Yellow sweet clover	*Melilotus officinalis*
ATCU	Cuneate saltbush or moundscale (USU 208-75)	*Atriplex cuneata*
XASA	Snakeweek (S-523-79)	*Xanthocephalum sarothrae*
HIJA	Galleta grass (A-12413-Viva)	*Hilaria jamesii*
ATCOR	Mat saltbush (S-538-79)	*Atriplex corrugata*
SUFR	Seepweed (USU-264-76)	*Suaeda fruticosa*
KOPR	Prostrate summer cypress (S-464-79)	*Kochia prostrata*
ATSA	Annual Twoscale (S-472-79)	*Atriplex saccaria*
ATAR	Annual Silverscale (S-526-79)	*Atriplex argentea*
ERMI	Perennial buckwheat (S-524-79)	*Eriogonum microthecum*

3. Section C

A mixture of thirteen species was broadcast seeded over the entire area on October 9, 1980. Due to the granular, rocky

nature of the soil plus shrinkage cracks no seed covering was done. Bitterbrush chips, approximately 1 yard square and at the rate of 2.5 tons per acre were superimposed October 15, 1980 on top of the seed. Four of the mulch plots were on top of the non-fertilized treatment and four on top of the fertilized treatment.

The following species were broadcast seeded using a portion of those seeded in Section B.

Symbol	Common Name	Scientific Name
GRBR	Spineless hopsage	*Grayia brandegei*
ATOB	Broadscale saltbush	*Atriplex obovata*
ORHY	Indian ricegrass	*Oryzopsis hymenoides*
ATCON	Shadscale	*Atriplex confertifolia*
ATCA	Fourwing saltbush	*Atriplex canescens*
SAVE	Greasewood (Sahara)	*Sarcobatus vermiculatus*
MEOF	Yellow sweet clover	*Melilotus officinalis*
ATCU	Moundscale	*Atriplex cuneata*
HIJA	Galleta grass (USU 208-75)	*Hilaria jamesii*
ATCOR	Mat saltbush (S-538-79)	*Atriplex corrugata*
SUFR	Seepweed (USU-264-76)	*Suaeda fruticosa*
KOPR	Prostrate summer cypress (S-464-79)	*Kochia prostrata*
ERMI	Perennial buckwheat (S-524-79)	*Eriogonum microthecum*

4. Section D.

   This is being left for spring transplants.

5. South of Section B on the slope (outside the fence).

   Four shallow trenches approximately 15 feet long were made horizontally on the slope. Seed containing the thirteen species was broadcast over the area on October 9, 1980 with no covering. The soil surface was severely cracked. The west portion was covered by a scattering of bitterbrush chips on October 15, 1980.

6. South of Section D (outside the fence).

A small amount of the seed mixture used in Section C was broadcast on the flat surface and also over the slope on October 9, 1980. The west part of this was covered with bitterbrush chips on October 15, 1980.

C. Wee Hope Mine Site (Plans 9 and 10)

1. Location A, Section A

Five shrub species were hill planted in the water harvesting study on October 29,1980. This was similar to the plantings made at Sahara and Repete Mines. The species direct seeded were:

Symbol	Common Name	Scientific Name
ATCA	Fourwing saltbush (S-536-79)	*Atriplex canescens*
ATCO	Shadscale (S-535-79)	*Atriplex confertifolia*
GRBR	Spineless hopsage	*Grayia brandegei*
SAVE	Greasewood	*Sarcobatus vermiculatus*
ATWE	Welsh saltbush (S-532-79)	*Atriplex welshei*

Transplants of the same species will be interplanted in the rows in early spring. Section B. at location A will also be planted in the spring with transplants.

2. Location B Southwest Corner

Sixteen small plots approximately 3 feet square were broadcast seeded using nine species after loosening the soil by dragging a pick through it. The entire area was raked following the seeding. Half of the plots (8) were left as a control and the other half (8) were mulched with bitterbrush chips at the rate of 2.5 tons per acre. The nine species seeded

and mulched on October 29, 1980 were:

Symbol	Common Name	Scientific Name
ATCA	Fourwing saltbush	*Atriplex canescens*
ATCO	Shadscale	*Atriplex confertifolia*
KOPR	Prostrate summer cypress	*Kochia prostrata*
SAVE	Greasewood	*Sarcobatus vermiculatus*
HIJA	Galleta grass	*Hilaria jamesii*
SPAI	Alkali sacaton	*Sporobolus airoides*
ELJU	Russian wildrye	*Elymus junceus*
ORHY	Indian ricegrass	*Oryzopsis hymenoides*
MEOF	Yellow sweet clover	*Melilotus officinalis*

3. Location B - Center two furrows

A pick was dragged down the two furrows which were made earlier for soil loosening. Seven species were planted October 29, 1980 in each row for a length of 6.5 feet each. Approximately 3 feet were mulched with bitterbrush chips and 3 feet left unmulched. The seven species planted included:

Symbol	Common Name	Scientific Name
ATWE	Welsh saltbush	*Atriplex welshei*
GRBR	Spineless hopsage	*Grayia brandegei*
KOPR	Prostrate summer cypress	*Kochia prostrata*
ATCU	Moundscale	*Atriplex cuneata*
ATCA	Fourwing saltbush	*Atriplex canescens*
ATCO	Shadscale	*Atriplex confertifolia*
SAVE	Greasewood	*Sarcobatus vermiculatus*

4. Location B East of furrows

Eight rows approximately 20 inches apart were seeded with fourteen species on October 29, 1980. Each species was seeded in approximately 40 inches of row length. All seeds were covered with soil. Four of the eight rows were surface mulched with

wood chips and four were not mulched. The fourteen species planted were:

Symbol	Common Name	Scientific Name
ELJU	Russian wildrye grass (Com)	*Elymus junceus*
ELJU	Russian wildrye grass (new selection)	*Elymus junceus*
HIJA	Galleta grass (Viva)	*Hilaria jamesii*
SPAI	Alkali sacaton	*Sporobolus airoides*
ORHY	Indian ricegrass	*Oryzopsis hymenoides*
MEOF	Yellow sweet clover	*Melilotus officinalis*
MESA	Alfalfa - yellow flowered	*Medicago sativa*
GRBR	Spineless hopsage	*Grayia brandegei*
ATCU	Moundscale	*Atriplex cuneata*
KOPR	Prostrate summer cypress	*Kochia prostrata*
ATWE	Welsh saltbush	*Atriplex welshei*
ATCA	Fourwing saltbush	*Atriplex canescens*
SAVE	Greasewood	*Sarcobatus vermiculatus*
ATCO	Shadscale	*Atriplex confertifolia*

5. Location B. South slope outside the fence.

Four horizontal beds approximately 20 feet long were dug in the south slope. Numerous seeds of five species were broadcast on these beds which were 6 to 10 inches wide and then the seeds were worked into the soil. It is anticipated that the banks above the beds will slip covering some of the beds. A flock of chuckers in the vincinity will probably consume some of the seeds along with rodents. The five species planted were:

Symbol	Common Name	Scientific Name
ATCA	Fourwing saltbush	*Atriplex canescens*
ATCO	Shadscale	*Atriplex confertifolia*
ATCU	Moundscale	*Atriplex cuneata*
GRBR	Spineless hopsage	*Grayia brandegei*
KOPR	Prostrate summer cypress	*Kochia prostrata*

D. Big Notch Planting Site (Plans 11, 12 and 13)

Five various plantings were made this post fall on the flat area south of the portal and one towards the bottom of the slope on the spoils (tailings).

1. Surface - Section A

Twelve grass species were direct seeded in rows approximately 20 inches apart and with approximately 40 inches of each species being planted on October 10, 1980 and then covered. There were four replications consisting of the following species:

Symbol	Common Name	Scientific Name
AGRE X AGSP	Hybrid	*Agropyron repens X Agropyron spicatum*
ELJU	Russian wildrye (selection)	*Elymus junceus*
BRIN	Smooth Brome	*Bromus inermia*
DAGL	Orchard grass	*Dactylis glomerata*
AGROP	? wheatgrass	*Agropyron spp.*
AGCR	Crested wheatgrass (Fairway)	*Agropyron cristatum*
ORHY	Indian ricegrass	*Oryzopsis hymenoides*
AGTR	Pubescent wheatgrass	*Agropyron trichophorum*
BRCA	Mountain brome	*Bromus carinatus*
AGIN	Intermediate wheatgrass	*Agropyron intermedium*
ELJU	Russian wildrye (comm.)	*Elymus junceus*
POCA	Canby bluegrass	*Poa canbyi*

2. Section B

Twelve forbs were direct seeded as above on October 10, 1980 using the same plan as for the grasses in Section A. The shrub species planted were:

Symbol	Common Name	Scientific Name
ACMI	Western Yarrow	*Achillea millefolium*
ARIU	Louisiana sagebrush	*Artemisia ludoviciana*
ONTR	Sainform (U1-78)	*Onobrychis transcaucasica*
KOPR	Prostrate summer cypress	*Kochia prostrata*
MEOF	Yellow sweet clover	*Melilotus officinalis*
BASA	Arrowleaf balsamroot	*Balsamorhiza sagittata*
CAOC	Yellow Indian paintbrush	*Castilleja occidentalis*
VIMU	Showy goldeneye (S-495-79)	*Viguiera multiflora*
MESA	Nomad alfalfa	*Medicago sativa*
PERY	Rydberg penstemon	*Penstemon rydberjii*
MESA	Yellow flowered alfalfa	*Medicago sativa*
ASCI	Cicer milkvetch	*Astragalus cicer*

3. Section C

Twelve shrub species were direct seeded similar to the grasses and forbs only in 40 inch row lengths on October 10, 1980. These included:

Symbol	Common Name	Scientific Name
CHNA	Rubber rabbitbrush (local)	*Chrysothamnus nauseosus*
PUTR	Antelope bitterbrush (USU-239-75)	*Purshia tridentata*
CAAR	Siberian peashrub (S-469-79)	*Caragana arborescens*
COAR	Common bladder senna (S-498-79)	*Colutea arborescens*
ATCA	Fourwing saltbush (S-536-79)	*Atriplex canescens*
SACE	Blue elderberry (S-545-79)	*Sambucus cerulea*
AMAL	Serviceberry (U 16-77)	*Amelanchier alnifolia*
RHTR	Skunk bush (S-491-79)	*Rhus trilobata*
SYOR	Mountain snowberry (U-19-75)	*Symphoricarpos oreophilus*
PERA	Squaw apple (U 8-70)	*Peraphyllum ramosissimum*
JUOS	Utah juniper (S-519-79)	*Juniperus osteosperma*
ARPA	Manzanita (local)	*Arctostaphylos patula*

4. Section D

This area will be planted in the spring with bare-root and container-grown transplants.

Section E

North of Section B and C on the flat sixteen 3 foot square plots were marked off afer ripping the soil with a pick. A seed mixture using the shotgun approach was broadcast over the surface with eight of the plots being mulched with bitterbrush chips and the other eight not mulched, but the seed raked in lightly. The wind was blowing so seeded much heavier than desired. The seed mixture planted October 30, 1980 included the following seed from Sections A, B and C with only the symbols being shown.

Grass	Forbs	Shrubs
BRIN	ARIU	CHNA
ORHY	ONTR	PUTR
BRCA	KOPR	CAAR
AGIN	MEOF	SACE
ELJU (comm.)	BASA	AMAL
POCA	VIMU	RHTR
	MESA (Nomad)	SYOR
	ASCI	JUOS
		ARPA

5. Section F

A broadcast direct seeding comparing four treatments was established October 30, 1980 on the lower part of the slope but still in spoil material. The four treatments were: (1) control (0); (2) control plus bitterbrush chip mulch; (3) surface raked and (4) surface raked plus a wood chip mulch. Seed was broadcast (using much more seed than desired due to windy conditions) following the rake treatment. The wood mulch was broadcast following the seeding, again having problems due to wind. Treatment 3 was gently raked following the seeding.

A small observation treatment was made along the west side where the spoil material was ripped deeper using a pick and then using the same seed mixture. A part of this was covered with a chip mulch and the other part as a control.

The seed mixture used included all of the 12 grasses and 12 forbs used in Sections A and B and eleven of the 12 shrubs in Section C plus two others. The symbols for the species planted plus the two additional shrubs were:

Grass	Forbs	Shrubs
AGRE X AGSP	ACMI	CHNA
ELJU (Selection)	ARIU	PUTR
BRIN	ONTR	CAAR
DAGL	KOPR	COAR
AGROP	MEOF	CEMO (Mountain mahogany *Cercocarpus montanus*)
AGCR	BASA	SACE
ORHY	CAOC	AMAL
AGTR	VIMU	RHTR
BRCA	MESA (Nomad)	SYOR
AGIN	PERY	PERA
ELJU (comm.)	MESA	JUOS
POCA	ASCI	ARPA
		PRVI (Chokecherry *Prunus virginiana*)

6. Section G (Miscellaneous)

A scattering of several species were container planted October 10, 1980 along the outer rim of the flat surface and just over the slope. Each received a quart of water following the planting. Approximate locations are shown on the field plan. Species planted included:

Symbol	Common Name	Scientific name
PIPO	Ponderosa Pine	*Pinus ponderosa*
QUGA	Gambel Oak	*Quercus gambelii*
POTR	Quaking aspen	*Populus tremuloides*

In addition to the above, six bare-root transplants of a spreading rabbitbrush (*Chrysothamnus linifolius*) were planted.

These same species plus additional trees, grasses, forbs and shrubs will be transplanted on the upper portions of the slope.

III. PRODUCING NURSERY PLANTING STOCK

Several hundred plants of the major species are being greenhouse grown in containers at the Snow Field Station. These are some of the same species that were planted by direct seeding this past fall. These will be used to complete the transplant sections at each site. Included are grasses, forbs, shrubs and trees. A bare-root nursery was also established on the Snow Field Station for comparison in methods of planting for a few of the species. Additional bare-root planting stock will be obtained as wildings near the mine sites if necessary.

Plantings at each site will be made as early as weather conditions permit with the Sahara and Wee Hope sites planned for March of 1981.

IV. SELECTING NATIVE SPECIES FOR REHABILITATION OF DISTURBED ARID SITES

Research on vegetative reclamation of arid sites has received very little interest because of the risks involved in securing plant establishment. Few plant materials of a suitable nature have been identified or developed for reclamation use. Further, plant attributes needed for arid lands reclamation have not been described except in a general way.

A MS thesis is being pursued in relation to the problems identified with the various study sites. This thesis will examine the vegetation in the vicinity of each study site and from this background of plant information develop a system for selecting native species suitable for use in reclamation of arid sites.

A. The Nature of the Problem

With the increasing population in the world, the need for additional agricultural land, rangeland improvement and new and expanded energy sources is increasing with an alarming rate.

Since neolitic times, man has practiced agriculture. In those times, shifting cultivation was the only way to keep production at a level to sustain a family group, in order to survive. After cultivating an area for a few years, man moved to another area, leaving the used site to return to its original condition after 25-30 years. With the increasing number of people, this sytem, still used in many areas, is getting shorter - too short for natural establishment and regeneration.

The resent droughts in the Sahel belt and in East Africa, illustrates what the result can be after an increasing number of people and livestock in marginal areas. Overgrazing and poor grazing management caused a rapidly declining range trend. The above mentioned droughts and future ones will cause an even faster deterioration of the arid range lands. If these lands are not revegetated with desired range species, mass starvation is eminent.

With the increasing population, the demand for energy and minerals also increases drastically. Large deposits of fossil and mineral fuels and minerals can be removed by surface mining. These mines create a serious disturbance of the ecosystem. The existing vegetation will be destroyed and subsurface material will be excavated and regraded, making it difficult for a new ecosystem to get established. Without treatment, the disturbed areas will be a source of high concentrations of particulate matter in the air and dissolved chemicals and sediments to the surface waters of the area. The most effective treatment is to revegetate with

well adapted plants, which will give a nearly permanent solution of the problem.

In the U.S. current and pending legislation requires that the revegetation is done with native plant species (Imhoff et al 1976, Federal Register 1977, 1979).

The choice of native species is justified for a number of reasons: (1) To reestablish the original vegetation, (2) To make the mined site less noticeable in the landscape, (3) native species have evolved under the environment of the area and (4) they offer a good opportunity to reestablish the original wildlife and range habitat.

What is lacking is a universal approach of selecting species for rehabilitating harsh arid sites. Plummer et al (1968), the USDA (1979) and the USDI (1977) provide some examples of attempts to provide criteria for selection, but except for the USDA, most authors only give a species list of plants suitable for revegetation.

This general and undocumented approach has one big disadvantage, as mentioned by Blauer et al (1975, 1976), McArthur et al (1979) and Van Epps and McKell (1979). The drawback of this approach is that wide variations exist among individual plants, within the same species, subspecies and even within biotypes. Differences in adaptation to climate, microclimate and soil, within a small area could result in a poor response of species chosen for use in revegetation.

The Institute for Land Rehabilitation (1979), the USDA (1979) and Van Epps and McKell (1978) give some major criteria for the selection of native species. Plummer et al (1968) published a list of criteria to consider in evaluating species for use in restoring big game ranges.

However, Plummer's list concentrates on plants growing in areas with an annual precipitation of 400 mm (approximately 16 inches) or higher.

This proposed research will concentrate on developing an effective approach for selecting species for arid land revegetation. The emphasis will lay on lands of less than 300 mm (12 inches) of precipitation. It will consist of evaluative criteria and some native species found on actual disturbed sites will be evaluated on how they meet these criteria. From this, a matrix will be developed to use in selecting species, which will employ a performance rating that ranges from 1-5. It should be recognized that the selected criteria will differ in importance according to the different postmining land use goals. A survey will be taken within a group of people with the knowledge of land reclamation. With their knowledge a second matrix will be developed rating the importance of the chosen criteria with the existing postmining land use goals.

The approach and some native species will be tested on the Colorado plateau. The Colorado plateau is one of the richest energy and mineral areas of the Western U.S. Large deposits of low sulfur coal, oil shale and uranium are found in this area. The generally arid climate has a mean annual precipitation that is below 375 mm (15 inches) (NAS 1974; USDI, 1978).

B. Hypothesis to be Tested

General

Criteria in addition to adaptation can be developed in choosing plants for revegetation of disturbed sites.

Specific hypothesis will be developed for each of the evaluation criteria.

Objectives

a. To develop criteria for the selection of species for revegetation of harsh sites, this approach should be applicable in arid lands, world wide.

b. To evaluate criteria in addition to adaptivity for revegetating harsh disturbed sites.

c. To test how some native and exotic species meet these criteria.

d. To compile a species list of plants occurring adjacent to South eastern Utah sites and rate these against the evaluative criteria developed in b and incorporate these in a matrix.

e. To develop a matrix, rating the importance of the evaluative criteria according to post mining land use goal.

f. For some sites, to compare the criteria developed in b, to the P.I.N. model (U.S.D.I. 1977) regarding plant survival and natural establishment.

C. Methodology

1. Literature Study

By examining the literature, a symposis will be made of what different authors, the federal and state government consider as being the major approach and criteria for revegetation. The Federal Register (1979), Imhoff et al (1976) and the Surface Mining Control and Reclamation Act (U.S. Congress, 1977) will serve as a starting point. All criteria will be evaluated. The goal for selecting criteria will be as Harthill and McKell (1979) describe to achieve a post-mined land use goal: "The post-mined land use goal defined here will be limited to ecological stability, by establishing a desirable, productive self sustaining plant community, with minimal long-term maintenance from the responsible managing party".

The process of developing criteria and rejecting the ones that are less appropriate for the study sites will be done on the basis of a search of the literature.

The criteria developed for this approach should be universally applicable in arid lands.

Through the literature and field studies, the criteria will be tested, after which they will again be evaluated against the Public Laws.

A system for the selection of species will be developed, with the emphasis on native species. As will be described in the Field Study and Greenhouse Study section, a species list will be made of plants growing in areas adjacent to the study plots and other disturbed sites. These species will be described through the literature. Next to the field and greenhouse studies, a literature study will also be done to evaluate the species on their performance towards some of the criteria which otherwise will take an extensive long term investigation.

An initial study on criteria, resulted in the following possible criteria:

a. Seed germination
b. Seedling vigor
c. Resistance to stresses
d. Resistance to grazing
e. Fire resistance
f. Cover
g. Erosion control

No definite decision has been made yet on which criteria will be selected. The above list can only be considered as an illustration of the approach.

2. Field Study

An inventory of the vegetation will be conducted of the following sites:

Uranium sites: Green River, Ut.
Blanding, Ut.
Fry Canyon, Ut.

Coal sites: Burnham, N.M.

Through these studies, a species list and a cover estimate will be obtained which will be used to set up a revegetation plan.

Of the most dominant species, characteristics will be measured in order to rate the species on how they perform towards the criteria. Having not yet established the criteria, it is impossible to get into detail in this proposal. However, one could consider features like: Seed production, root system, cover of individual plants, preference of livestock and wildlife for a certain species, resistance to stresses and others.

In the spring of 1981, the above mentioned uranium sites, will be revegetated with a number of species found in the area and species expected to have a high potential. Throughout the summer of 1981, the plots will be monitored to obtain an initial number for survival.

From other disturbed sites in the area an inventory will be be made on the success of artificial and natural revegetation. This will be done by visiting B.L.M. offices in the area, to obtain the locations of a number of sites in the area and by visiting abandoned mine spoils.

3. Greenhouse Studies

Greenhouse studies will be used to develop information as to how some selected species, meet certain field requirements. The characteristics being evaluated, are short term ones, due to time restrictions. One could consider: Speed in germination, seedling growth rate and seeding competition. This list is not a definite one, considering the evaluative criteria are not yet developed.

4. Statistical Analyses

For the greenhouse studies, statistical methods will be developed to inable interpretation. As the project proceeds, it will give direction to particular greenhouse studies to be conducted and statistically evaluated. It might be necessary to develop a regression model between selected species and the criteria.

5. Usefulness of the Study

In 1974, surface coal mining had left nearly a million acres in need of reclamation (Davenport, 1979). The literature is so scattered and divided on what the approach should be, that it is necessary to try to summerize and synthesize the literature. Many companies are unfamiliar with species capability and the available literature.

Furthermore the approach should have wide applicability, for as mentioned in the introduction, the need for a proper revegetation plan is universal for arid lands.

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V. FIELD STUDIES

Vegetation Analyses of the Three Research Sites

A. Sahara Study Area

Site 1. This site is on the top of the mesa. The topography is slightly sloping. Dominant annual plants are *Eroiogonum* species, *Salsola pestifer* and *Bromus tectorum*. Rocky soil, from shale to sandy on the rocky ridges some *Feaxinum anomala*.

Site 2. This site is located on lowland flat, where sandy clay soil is predominant.

Vegetation Analysis

Species	% Cover (+ = trace) Site 1	2
Astragalus spp.	.1	.8
Artemisia bigelcvii	.7	-
Hilaria jamesii	.7	.1
Xanthocephalun sarothrae	.4	-
Oryzopsis Hymenoides	.3	.3
Aster spp.	.1	.2
Eriogonun spp.	+	.2

Vegetation Analysis

Species	% Cover Site 1	(+ = trace) 2
Atriplex confertifolia	.1	+
Atriplex cuneata	.1	+
Chrysothamnus greenei	.1	+
Ephedra nevadensis	.1	-
Ephedra viridis	.1	+
Muhlenbergia mundula	-	.1
Sarcobatus vermiculatus	-	.1
Abronia fragrans	-	+
Artemisia filifolia	-	+
Atriplex corrugata	+	+
Chrysothamnus nauseosus	-	+
Descurainia spp	+	-
Grayia brandegei	+	-
Opuntia spp	+	-
Phlox spp	+	-
Sphaeralcea spp	+	-
Total Cover	2.8	1.8
Variance	3.7	.6
Sample size	22	11
Optimum size	49	2

Remarks: Site 1 area to small for adequate sampling.

In the disturbed area around the plots, cover data to low for sampling Species are:

Aster spp

Astragalus spp

Atriplex canescens

Atriplex confertifolia

Atriplex jonesii

Atriplex obovata

Bouteloua gracilis

Chrysothamnus greeneii

Chrysothamnus nauseosus

Muhlenbergia mundula

Eriogonum spp

Grayia brandegei

Hilaria jamesii

Oryzopsis hymenoides

Sarcobatus vermiculatus

Sitanion hystrix

Sphaeralcea spp

Xanthocephalum sarothrae

B. Weehope Study Area

Site 1. North of fenced plot 5-15% slope gravelly, sandy soil *Salsola pestifer* and *Bromus tectorum* dominated.

Site 2. East of plot rocky sandy loam 5% slope west aspect juniper/blackbrush dominated.

Site 3. South of plot 10% slope northeast aspect sandy gravelly with *Bromus tectorum*.

Site 4. West 206 slope gravelly clay.

Vegetation Analyses

Species	% Cover Sites (+ = trace)			
Sites	1	2	3	4
Juniperus osteosperma	-	3.5	-	.7
Hilaria jamesii	.7	.3	.6	2.1
Coleogyne ramosissima	-	.8	2.2	.3
Atriplex confertifolia	1.5	-	.1	1.4
Eriogonum spp	-	-	-	.6
Xanthocephalum sarothrae	+	.6	+	-
Ephedra virdis	-	.1	.5	-
Rhus Trilobata simplicifolia	-	.4	-	-
Chrysothamnus greenei	-	+	.2	+
Aster spp	-	.1	+	+
Astragalus spp	.1	-	-	+
Kochia americana	.1	-	-	+
Opuntia spp	.1	+	-	-
Orizopsis hymenoides	-	.1	+	-
Yucca spp	-	.1	+	.1
Sitanion hystrix	-	+	-	+
Suffrutescent plant 1	-	-	-	+
- - 2	-	-	+	-
Average % cover	2.5	6.0	3.6	5.2
Variance	2.9	6.9	6.7	33.5
Sample size	19	14	13	21
Optimum size	34	82	128	2215
at 10% of time mean 90% confidence				

Species found indistrubed area b. old mine spoils:

Astragalus spp

Atriplex confertifolia

Chrysothamnus nauseosus

Eriogonum spp

Grayia brandegia

Hilaria jamesii

Kochia americana

Sitanion hystrix

Xanthocephalum sanothrae

C. Repeat Study Area

Site 1. On top of mesa dominant plants are *salsola pestifer* and *Bromus tectorum* dominated. Slope is 5% in all directions. Sandy clay soil dominates.

Site 2. As 1 but more sandy.

Site 3. Mixed riparian habitat of streambeds/saline lowlands with *Bromus tectorum* dominated. *Sarcobatus vermiculatus* is the most noticeable shrub. The soil is gravelly sandy clay.

Site 4. East of mine south aspect 10-15% slope gravelly shale *Bromus tectorum* dominated.

Site 5. West approx. 1 mile down the road gravelly clay 10% slope to flat. Most SW aspect *Bromus tectorum* dominant species.

Vegetation Analysis

Species	% Cover (+ = trace)				
Sites:	1	2	3	4	5
Artemisia bigloveii	-	2.6	-	-	-
Xanthocephalum sarothrae	1.0	1.9	.4	.1	.3
Atriplex confertifolia	.4	-	.3	1.6	+

Vegetation Analysis

Species	% Cover (+ = trace)				
Sites:	1	2	3	4	5
Hilaria jamesiia	.3	+	+	1.0	.4
Astragalus spp	.1	-	.1	.9	-
Sporobolus cryptandrus					
Atriplex obovata					
Artemisia frigida					
Aster spp					
Kochia americana					
Chrysothamnus nauseosus					
Sarcobatus vermiculatus					
Atriplex jonesii					
Cowania mexicana standsburiance					
Grayia spinosa					
Opuntia spp					
Oryzopsis hymenoides					
Tetradymia canescens					
Artemisia filifolia					
Artemisia spinescens					
Chrysothamnus greenei					
Sphaeralcea spp					
Sporobolus airoides					
Unknown forb 1					
Unknown forb 2					
Average % cover					
Variance					
Sample size					
Optimum at 10% true mean					
confidence					

Species found around spoils

Ephedra virdis

Artemisia frigida

Artemisia spinescens

Yucca spp

Fishhook cactus

Atriplex canescens

Bouteloua eriopoda

Bouchloe dactyloides

Eriogonum spp.

Kochia americana

Grayia spinosa

Annuals

Atriplex palii

Atriplex argentia

Kochia scoparia

Salsola pestifer

Bromus tectorum

VI. APPENDICES

Research Site Plans

A. Sahara Mine Site

B. Wee Hope Mine Site - Location A

C. Wee Hope Mine Site - Location B

D. Repete Mine Site

E. Sahara Planting Plan - Section 0 (on slope)

F. Sahara Planting Plan (outside fenced area to the West)

G. Repete Planting Plan - Section A & B

H. Repete Planting Plan - Sections C & D

I. Wee Hope Planting Plan - Site A

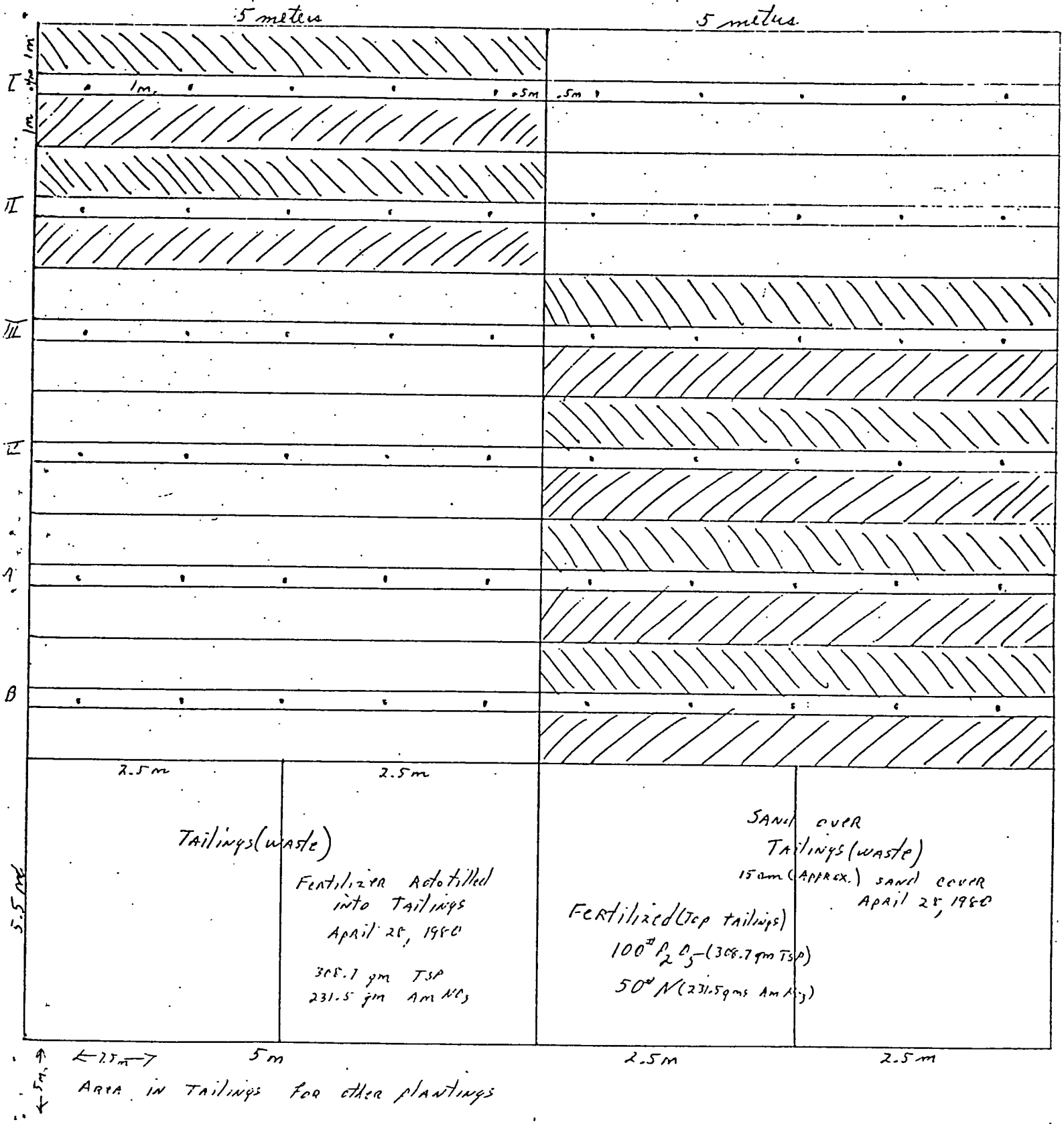
J. Wee Hope Planting Plan - Site B

K. Big Notch Planting Plan

L. Big Notch Planting Plan Sect. A-B-C-D Flat area

M. Big Notch - Slope

Jamhara Mine Site
Plot Preparation and Field Plan



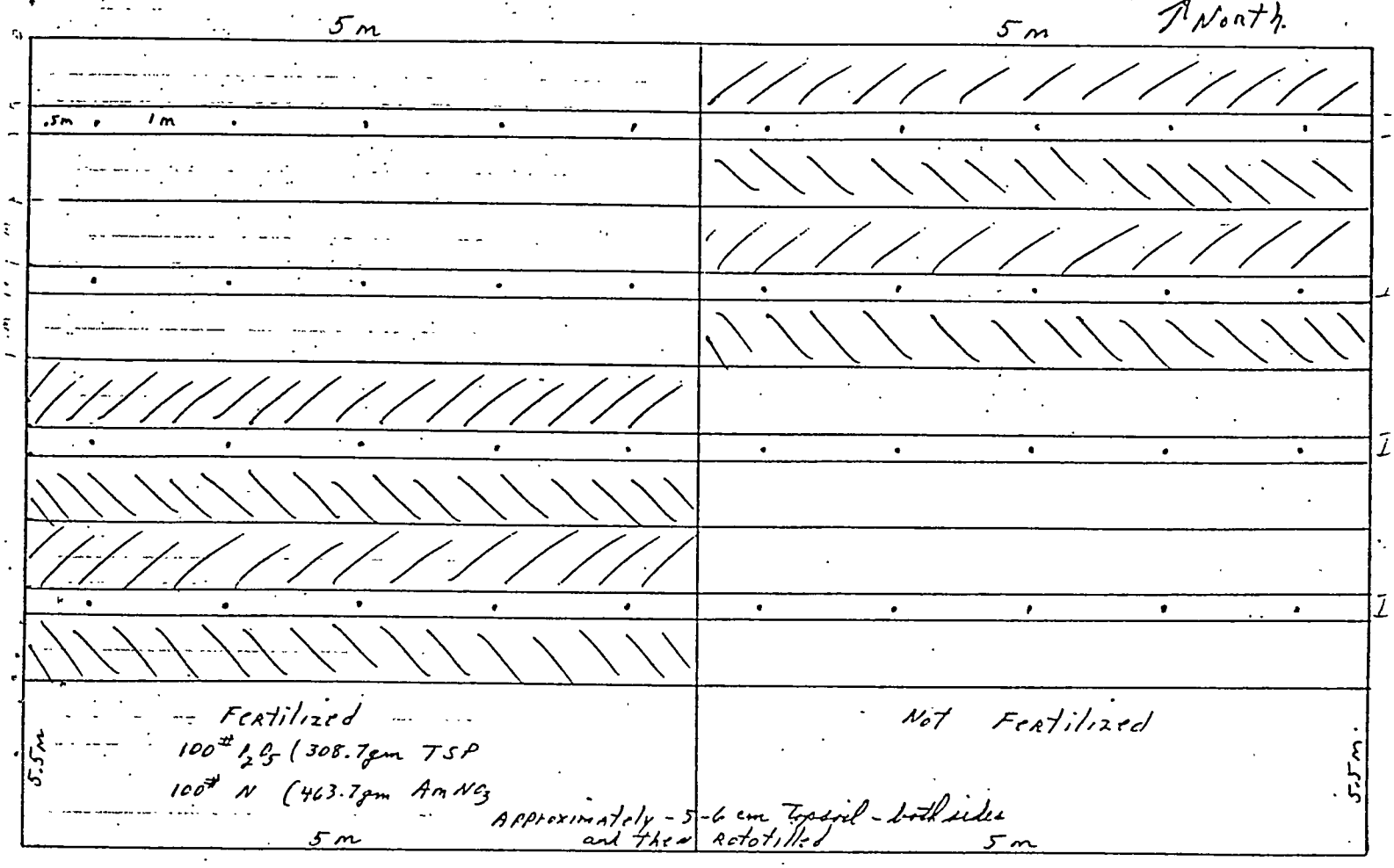
Reps 1, 2, 3, 4 Received 2 lbs shavings per plot (4 lbs per rep) April 4, 1980

45.4 gms Treble superphosphate per plot
34.1 gms Ammonium Nitrate per plot

Above placed on top of waste in trench and then covered with sand 3-4 inches and then Rototilled. Reps A+B were fertilized but no shavings

PLAN 2.5.5

Wee Hope Mine Site
Location A
Plot Preparation and Field Plan



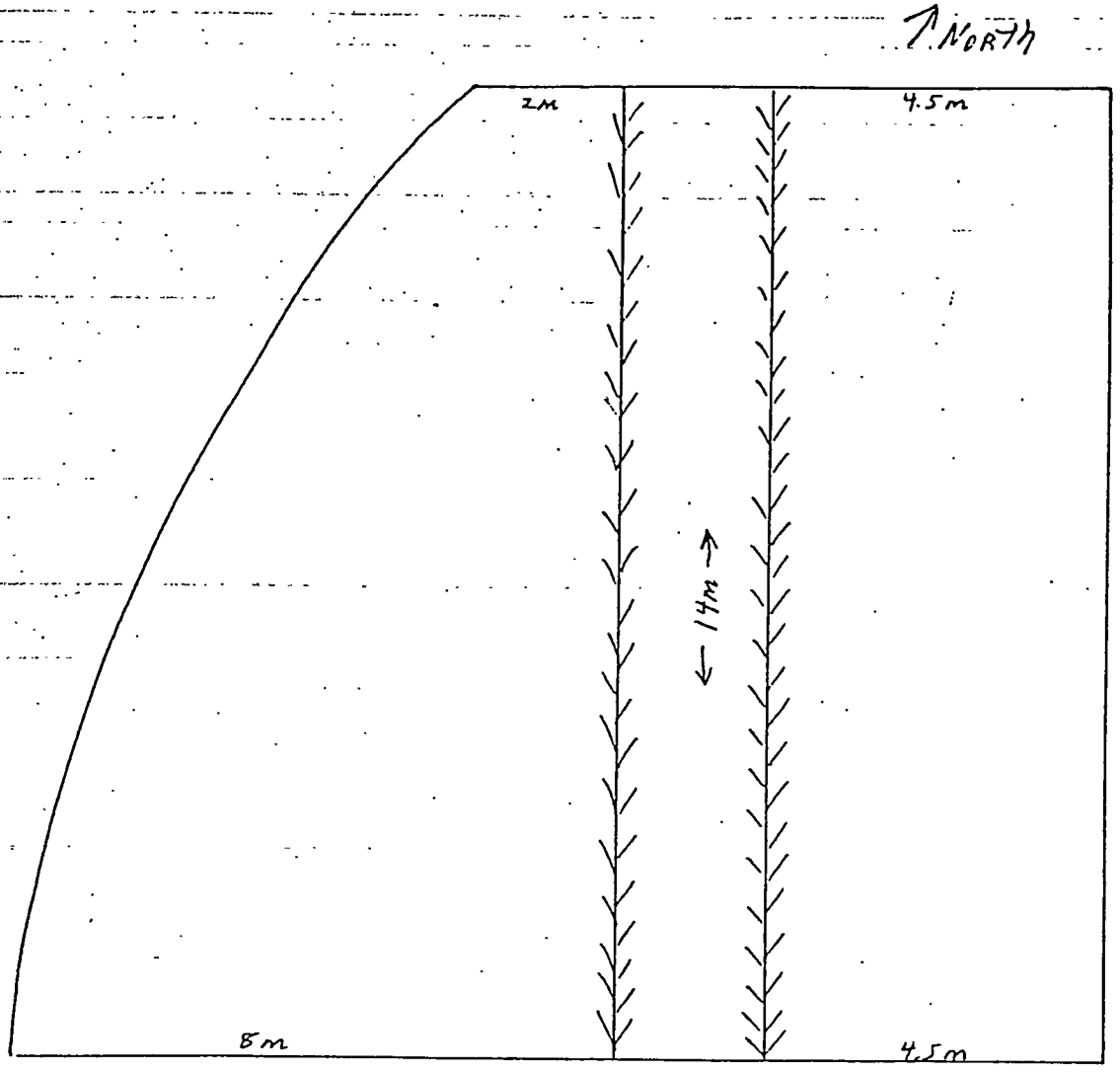
Reps I – IV received 2 bbls (908 gms) shavings per plot (4 lbs or 1816 gms per sq.) April 30th – May 1, 1980

Each plot received fertilizer at rate of:
- 45.4 gm treble super phosphate per plot
- 34.1 gm ammonium Nitrate per plot

Fertilizer placed in bottom of trench then covered with shavings and then 8 – 12 cm of top soil. all well rototilled for mixture.

PLAN 3

Wee Hope Mine Site
Location B

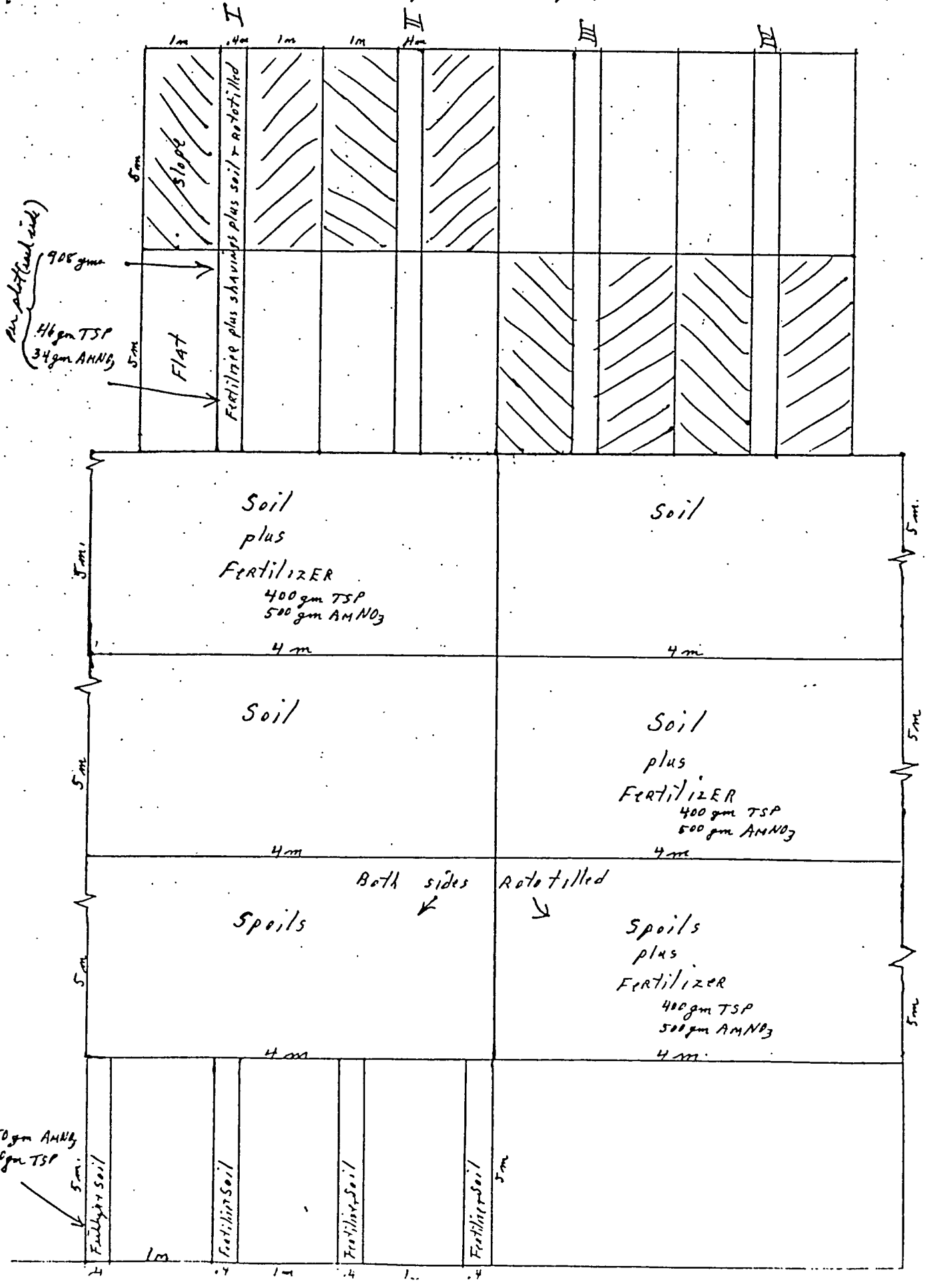


AREA leveled and furrows made MAY 1, 1980
for miscellaneous shrub-ford + grass plantings

June 16, 1980

Plan 4

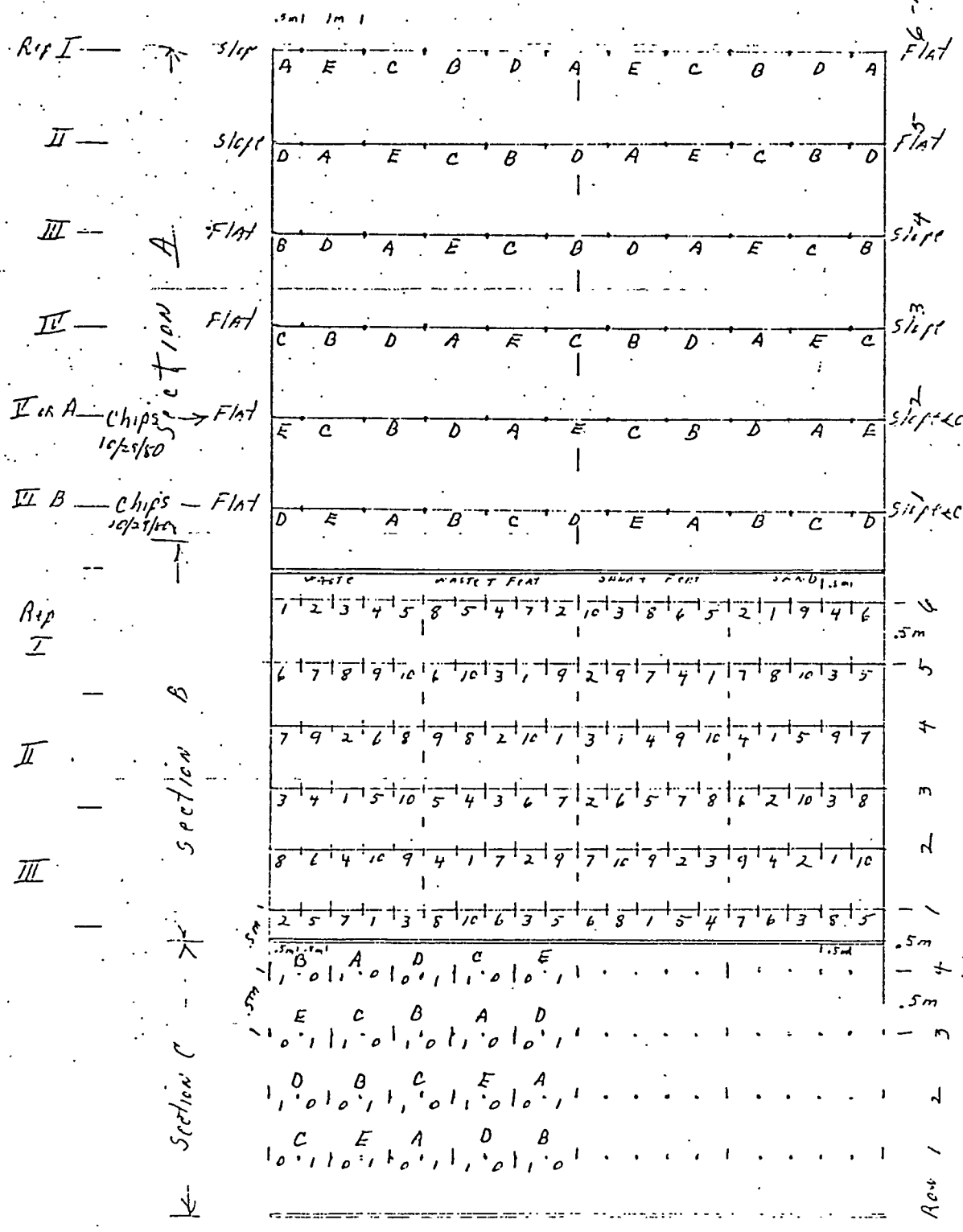
...epete Mine Site
Plot Preparation Plan



PLAN 3

Section D (on slope)

W ↑→N Sahara Planting Plan



Species

Direct seed 10/10/50

A – ATCA
B – ATCO
C – ATCU
D – SAVE
E – GRBR

Transplants

a –
b –
c –
d –
e –

Species

Direct seed 10/10/50

1 HIJA
2 ATCA
3 ATCON
4 SPAI
5 ATCCR
6 ERID
7 OAHY
8 ATWE
9 CELA
10 SPHA

Species (section C) South side Direct seeded

A ATCA } same as sect. A
B ATCO
C ATCU
D SAVE
E CRBR

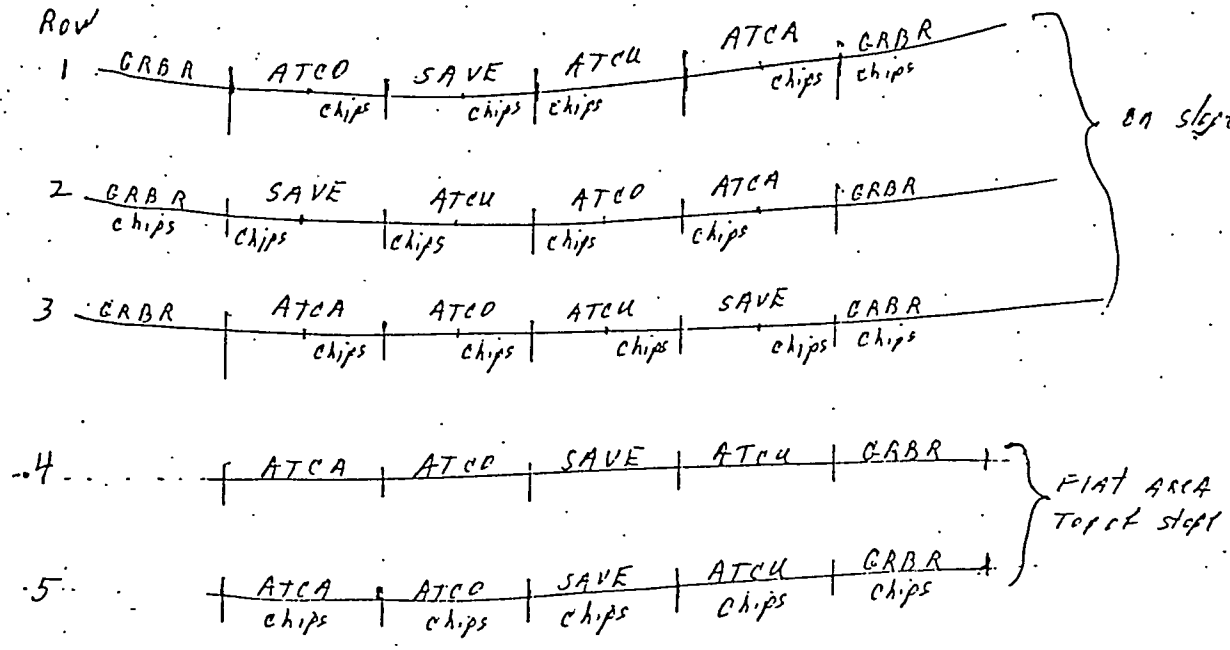
0 = no chips
1 = chips

PLAN 6

SAHARA PLANTING PLAN

N →

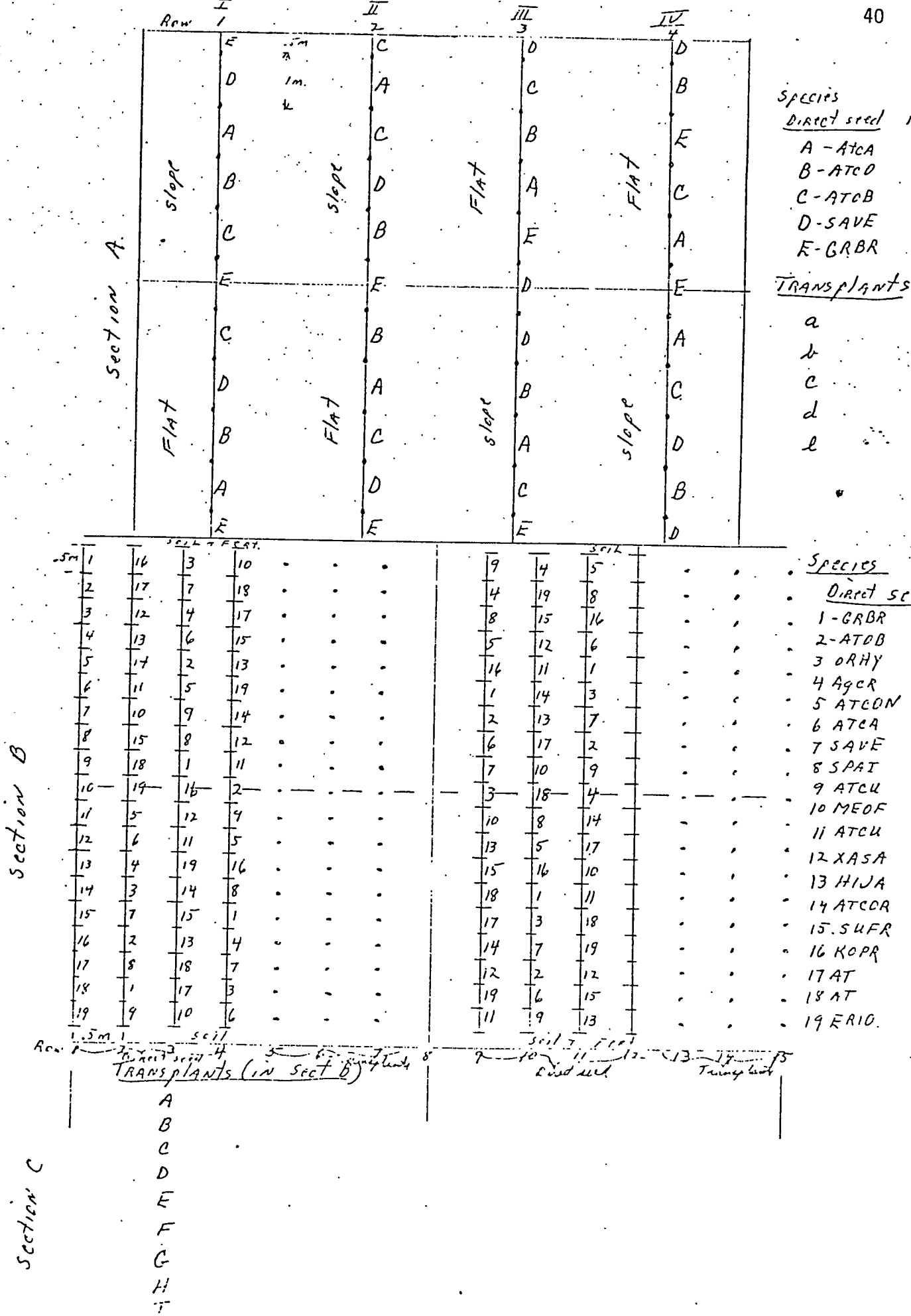
Section D (Outside Fenced AREA to the West



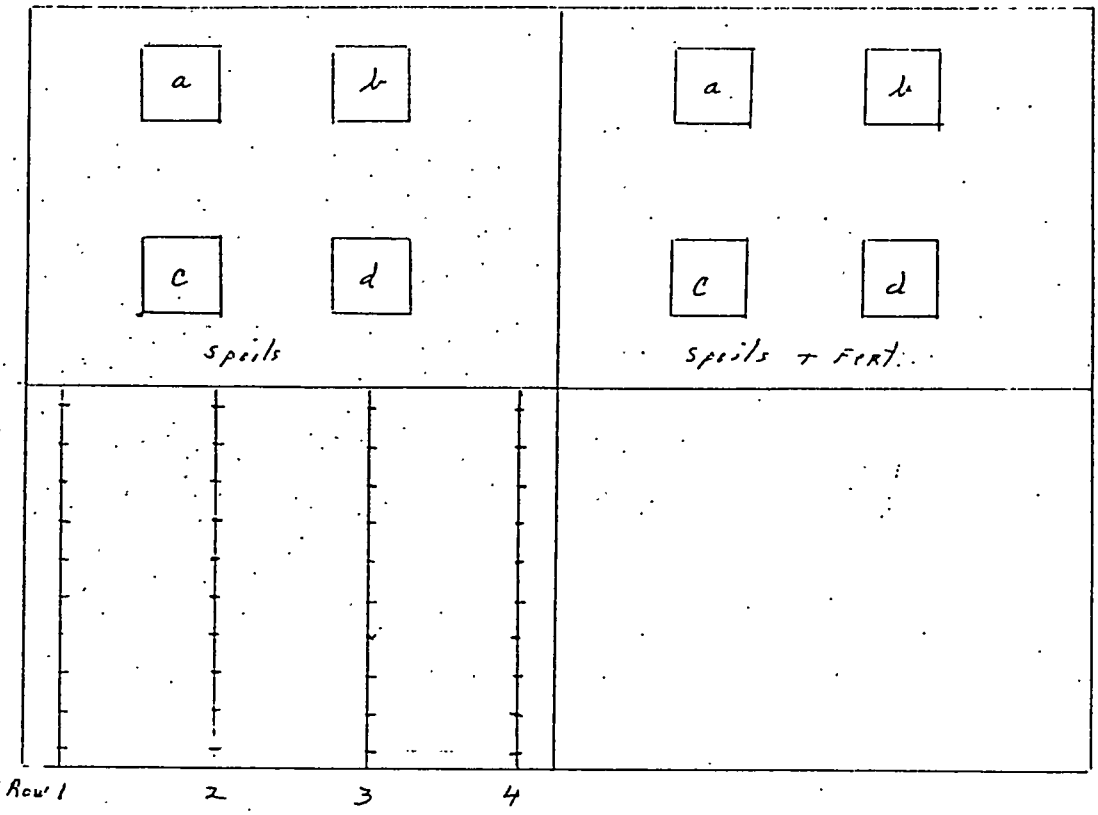
Direct seeding oct 29, 1980

Species same as Section A (same source)

Detailed Planting Plan Sections A + B



Rejate Existing PLAN - Sections C & D and Slope



Species

Section C -

Direct seeding, Oct 9, 1980, by broadcasting the following mix (weighing of species not done prior to seeding). Mixture made from seed used in section B.

1 - GRBR
2 - ATOB
3 - ORHY
5 - ATCON
6 - ATCA
10 - MEOF
11 - ATCU
13 - HIJA
14 - ATCOR
15 - SUFR
16 - KOPR
19 - ERIO
+ SAVE (from SAHARA site)

Note: Shredded bitterbrush at the rate of 2½ Ton/Acre (1.1 #/square) was applied Oct 15, 1980 to 8 squares As shown.

Section D

a -
b -
c -
d -
e -
f -
g -
h -
i -
j -

Slope

South of section B

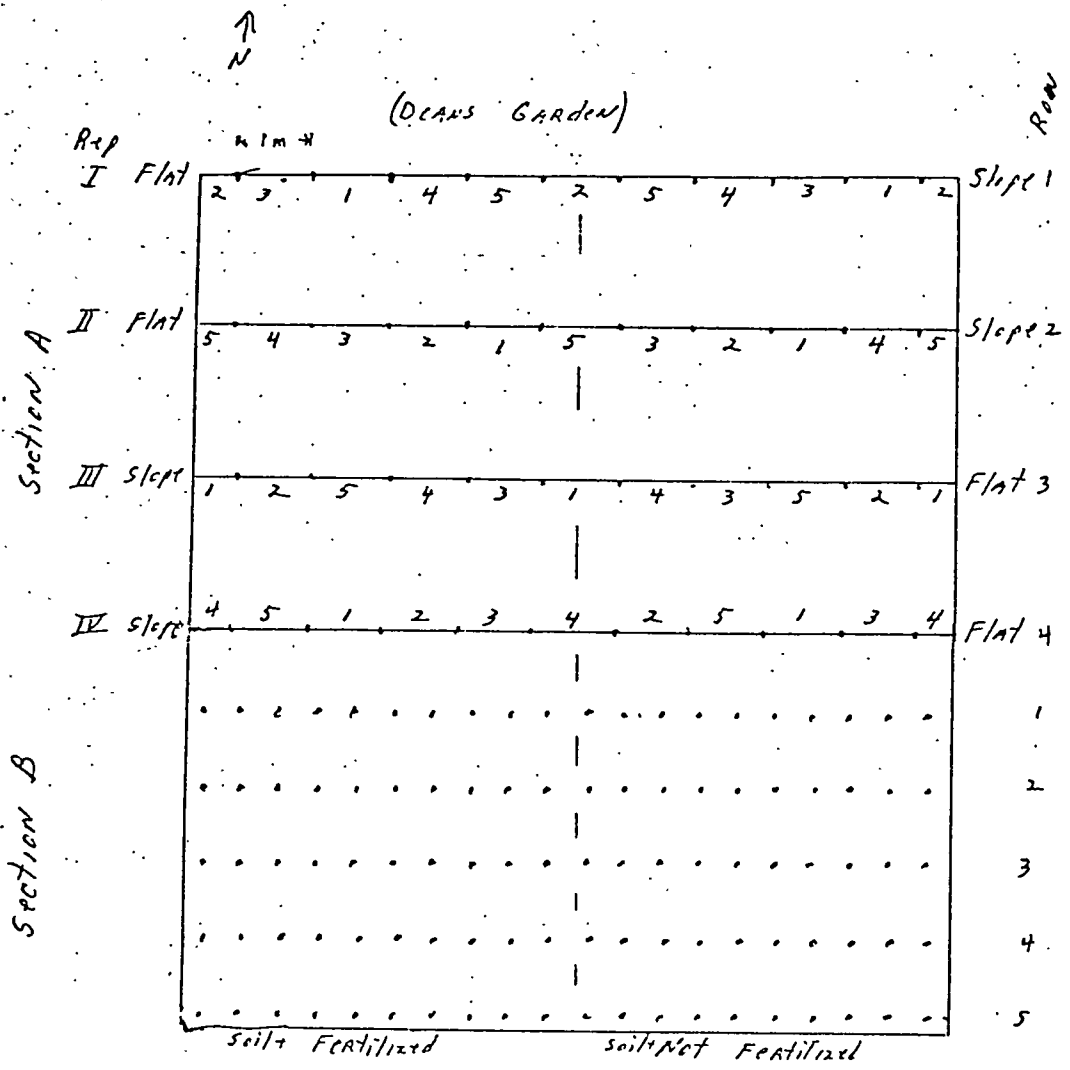
Section B

Four shallow trenches (horizontal) were made on the slope and then the seed mixture from Section C was broadcast over it and the slope between on Oct 9, 1980. On Oct 15, 1980 shredded bitterbrush was broadcast over the west portion of it including slope and trenches.

South of Section D.

Seed mixture from Sect C. was broadcast over the slope and on top of the slope Oct 9, 1980. Shredded bitterbrush was broadcast over a

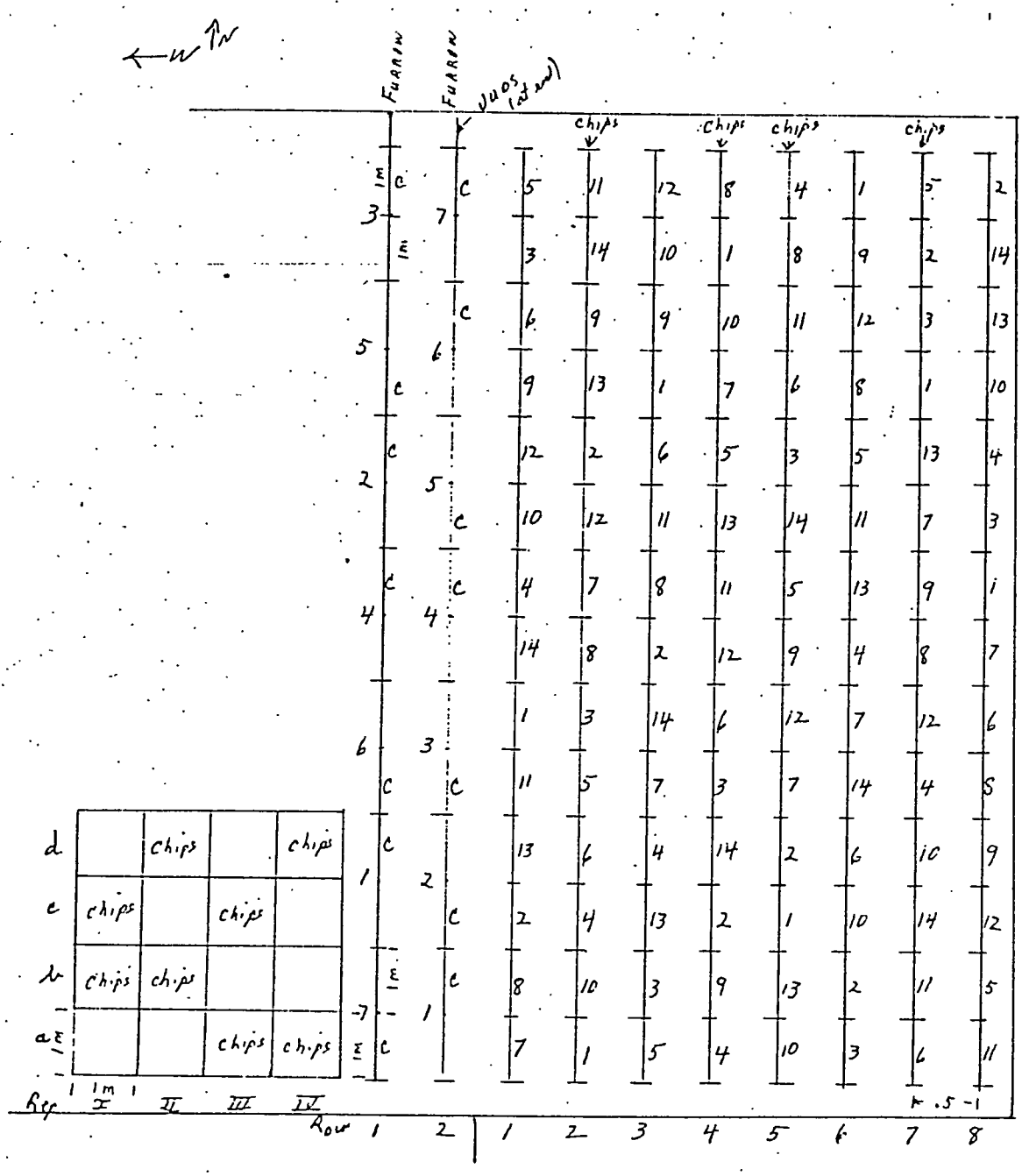
Wee Hope Planting Plan - Site A



Species
Direct seeded Oct 29, 1980
1 ATCA
2 ATCO
3 GABR
4 SAVE
5 ATWE

Transplants
a
b
c
d
e

West Slope Planting PLAN - Site 45

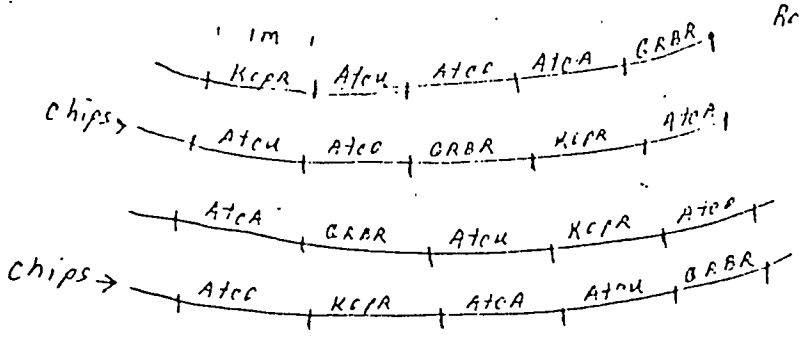


FURROW PLANTING
Direct seed (Oct 29, 19
1 ATWE
2 GRBR
3 KOPR
4 ATCU
5 ATCA
6 ATCO
7 SAVE
c = chip

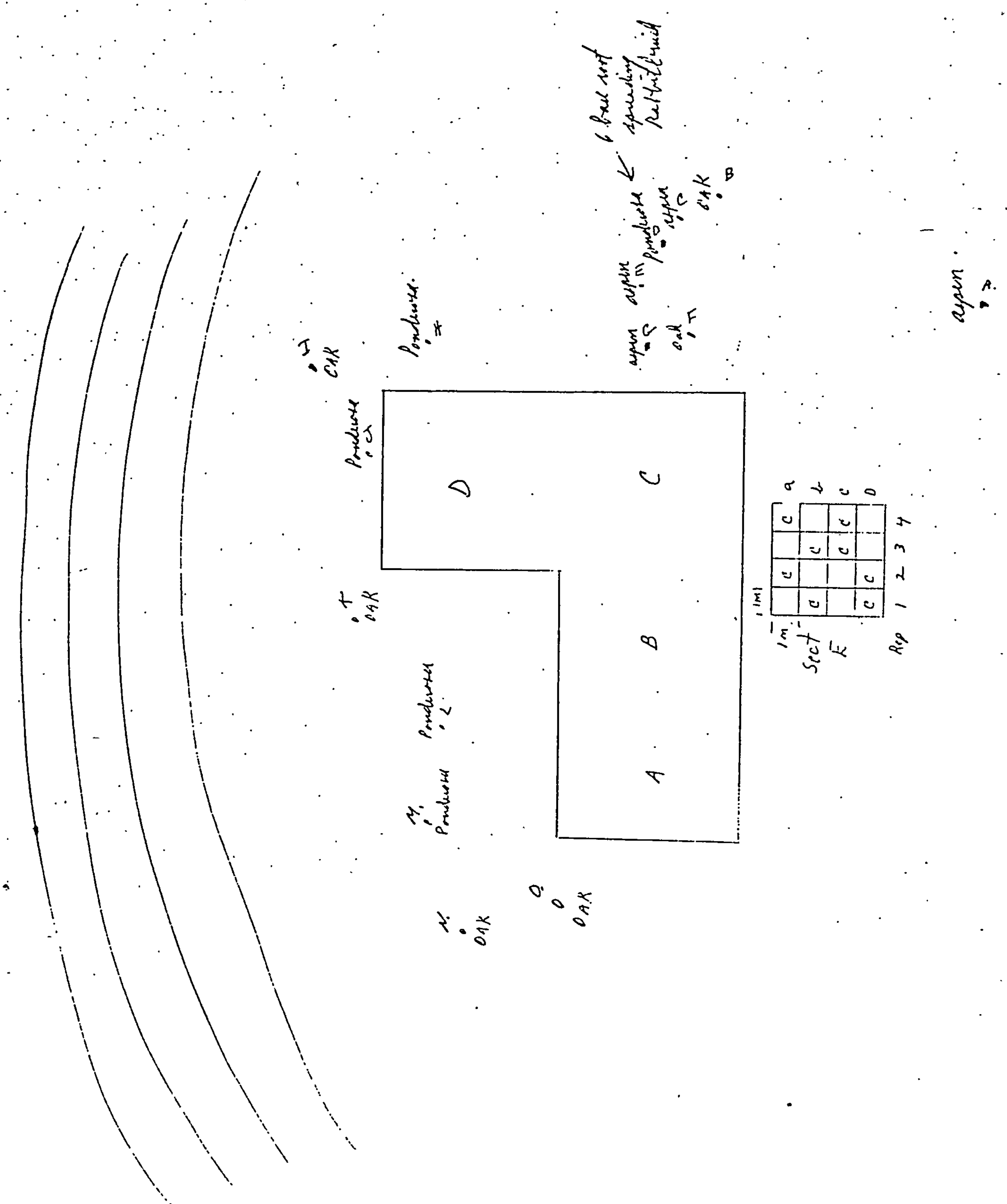
FLAT PLANTING
Direct seed (Oct 28 1986
1 Elju -
2 Elju - 1-15 also CAr
3 Hija
4 spai
5 CRHy
6 Mecf
7 MesA
8 GRBR
9 ATCU
10 KOPR
11 ATWE
12 ATCA
13 SAVE
14 ATCO

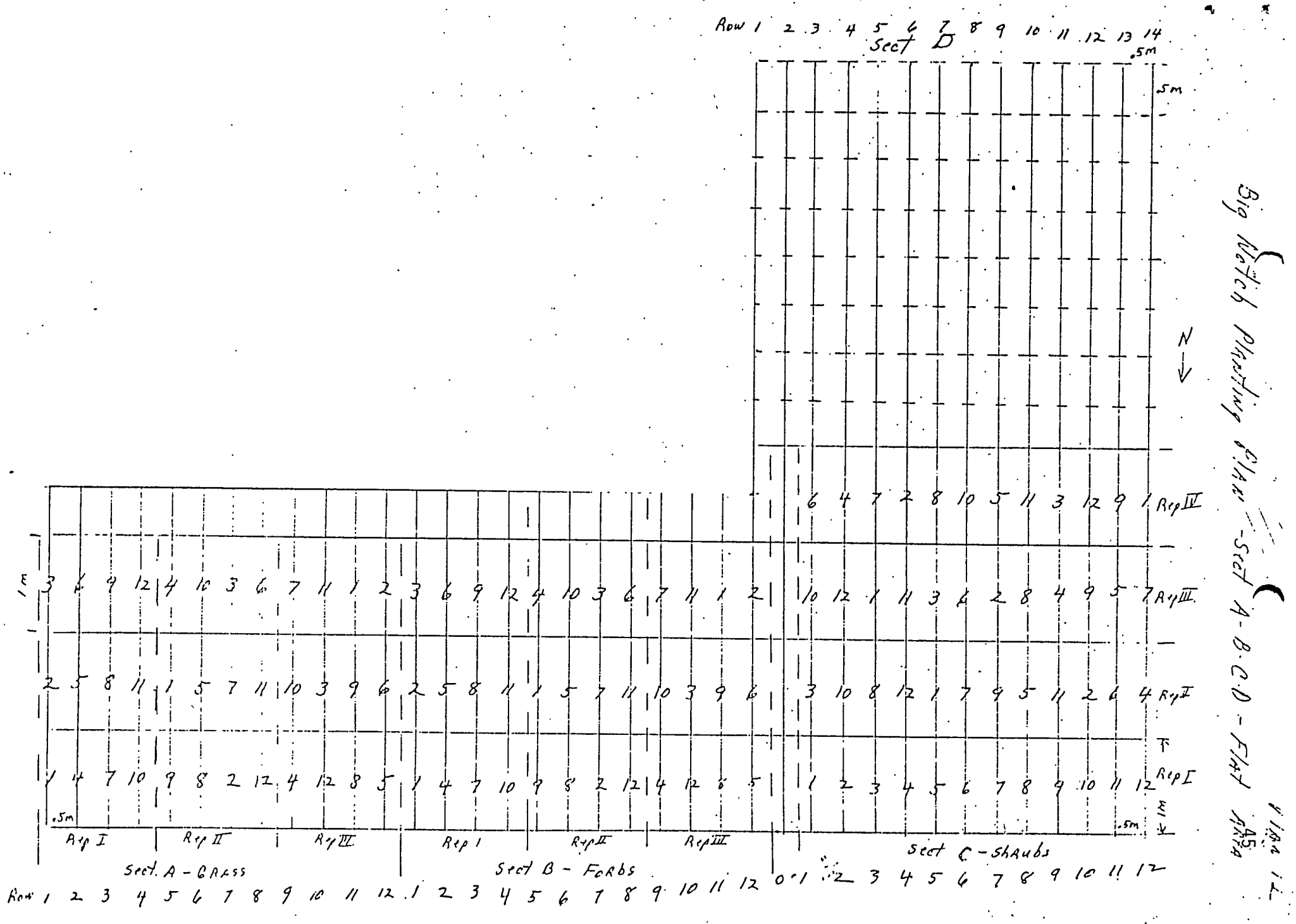
Rows 2, 4, 5, 7 were completely chipped.

Seed Mix - Direct (South west corner
5 - ATCA
6 - ATCO
3 - KOPR
7 - SAVE
3 - Hija
4 - spai
2 Elju
5 - CRHy
6 - Mecf.



Big Notch Planting Plan




Big Rotich planting plan - Sect A-B-C-D - Flat plan
Sect D
Row 1 2 3 4 5 6 7 8 9 10 11 12 13 14
.5m
5m
N
Rep III
Rep III
Rep II
Rep I
Sect A - Grass
Sect B - Forbs
Sect C - shaubs
Rep I
Rep II
Rep III
Rep I
Rep II
Rep III
Row 1 2 3 4 5 6 7 8 9 10 11 12

↑ N

Big notch = slope

O O- Reed trees

Sect F

		1	2m	1	
	2M	RAKed	0	0 chips	RAKed + chips	a
A Pick point		0	RAKed	RAKed	0 chips	b
B Pick point		RAKed + chips	0 chips	RAKed + chips	0	c
		0 chips	RAKed + chips	0	RAKed	d
		Rep I	II	III	IV	